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POSTHARVEST SPECIALIST PROGRAM

PROJECT #97000171

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1. ABSTRACT

Storage of fresh saskatoon fruit in modified atmosphere (MA) bags held at 0°C was effective at suppressing microbial growth, minimizing changes in fruit quality, and extending shelf-life to more than 2 weeks. Loss of peel colour in red-skinned potato cultivars did not occur during five months of cold storage; colour loss may occur during potato distribution and marketing. The cultivars Cherry Red and AC Peregrine were firmer and redder than Norland. Coleslaw from the cabbage cultivars Almanac, Cecile, Hinova, and Vantage Point had consistently less browning after storage than the cultivar Lennox, the processing industry's standard.

2. EXECUTIVE SUMMARY

The mandate of this program was to address some of the postharvest needs of Saskatchewan's Horticulture sector, and in particular, to address issues of postharvest quality in the key areas of fruit and vegetable production.

2.1. Shelf Life Extension of Fresh Saskatoon Fruit

Rapid deterioration of fruit quality after harvest due to physiological and biochemical

changes within the tissue, limits the marketing potential of fresh saskatoon fruit. Traditionally, saskatoon fruit either are consumed within a short period of time following harvest, or are frozen immediately after harvest and subsequently processed into various value-added products. Currently, there is a lack of information on how long saskatoon fruit can be stored after harvest with no loss of quality. There is also a lack of appropriate technology to extend the shelf life of fresh fruit. Low temperature storage of fresh horticultural produce, in combination with the use of modified-atmosphere (MA) packaging material, is a widely recognized method to extend shelf life, but its application to saskatoon fruit requires investigation. This methodology can be applied to both small and large volumes of fruit The objectives of this component of the program were: 1) to examine the application of low temperature storage, in combination with modified-atmosphere packaging material, to extend the shelf life of fresh saskatoon fruit, in both small and large volumes; 2) to document the changes in fruit quality under differing environmental conditions such as time of harvest, method of cooling, and method of storage; and 3) to develop an appropriate postharvest management protocol to extend the shelf-life of fresh saskatoon fruit.

Postharvest management and storage conditions of fresh saskatoon fruit were examined in 1998 and 1999 for their effect on fruit quality and shelf life. The effect of different harvest times and cooling methods on fruit quality were investigated. In this study, harvesting fruit earlier in the day when temperatures were cooler did not result in a consistent improvement in fruit quality, or using chilled water to cool the fruit following harvest did not make a difference in fruit quality after 2 weeks in cold storage.

Fruit of four saskatoon cultivars, Smoky, Pembina, Honeywood and Thiessen were harvested for 3 years (1998-2000) and stored for a number of weeks in MA bags at 0°C to determine the effect of modified atmosphere storage on fruit quality and shelf life extension. In 2001, fruit of Smoky, Honeywood and Thiessen were stored in freezer or MA bags at 0 or 5°C. At the time of harvest, and every subsequent week of storage thereafter, fruit quality was assessed. In 2000 and 2001, bulk storage of trays of 4 to 5 kg of fruit were stored at 0°C for 2 weeks in MA packaging.

Storage in MA bags was very effective at suppressing microbial growth. Fruit in MA bags could be stored at 0°C for up to 28 days without a significant increase in microbial content. Even after 7 to 8 weeks in storage in MA bags in 1998 to 2000, no microbial growth was noticeable on saskatoon fruit. In contrast, fruit stored in freezer bags had a 33 fold increase in microbial content after only 3 weeks. The plastic of MA bags creates a high CO_2 and low O_2 concentration within the bags; this atmosphere is unfavourable for aerobic microbial growth. Gas content in small MA bags reached levels of up to 12 to 18% CO_2 and 1% O_2 after 3 weeks in storage. Anaerobic respiration during storage in MA bags was not significant. Storage at 0°C was more effective at reducing microbial growth than at 5°C on fruit stored in freezer bags. However, the lower temperature did not generate significant further reductions in microbial growth if fruit were stored in MA bags.

Changes in fruit quality occurred during cold storage. Fruit firmness, pH and hue angle

(redness) increased, while titratable acidity, soluble solids and Hunter L value (colour lightness) decreased during storage. These general trends occurred in most years of the study, except for fruit soluble solids content which did not change significantly during storage in MA bags in the first 3 yrs of the project, and hue angle, which fluctuated or experienced a slight decrease during storage in 1998 and 1999. After 3 weeks in storage, these fruit quality changes, except for texture and titratable acidity, were minimal for the most part and not likely to be detected by the consumer. Following a 3 week storage period, fruit firmness increased by approximately 85% in 2000 and 2001. It is not known what caused this increase in firmness as previous research has reported that saskatoon fruit became softer in texture during storage (Rogiers and Knowles, 1998). Up to 67% of fruit titratable acidity was lost after 3 weeks in storage. This loss was decreased by 37% and 15% if fruit were stored in MA bags or at 0°C, respectively. It is not known at what point these changes in fruit texture and flavour become undesirable to the consumer. Cultivars with a soft texture and high titratable acidity, such as Thiessen, may be more suitable for cold storage. In this study, after 3 weeks in storage, fruit of Thiessen reached levels of firmness and acidity equivalent to that of Smoky and Honeywood at the time of harvest. Changes in other fruit quality parameters, except for texture, were reduced by up to 5% by storage in MA bags or at 0°C. Storage in MA bags or at a lower temperature results in a reduction of fruit respiration, which retards the loss of fruit quality that occurs during storage. For all cultivars, changes in fruit quality were minimal or not significant after 2 weeks in storage in MA bags.

MA packaging was more effective in reducing microbial growth and improving fruit quality during storage in small bags than during bulk storage in large bags. This is probably associated with the ratio between bag size and fruit quantity, and the resultant change in the air composition in the bags. The large MA bags probably had a greater air to fruit ratio and thus the atmosphere in these bags probably was not altered as much as in the smaller bags. In addition, some air was removed from the smaller bags at the time of sealing. It is evident that the bag size to fruit volume ratio needs to be considered when using MA packaging and/or gas composition adjusted using an injection of the appropriate gas mixture.

Based on the results of this study, saskatoon fruit should be able to be stored in MA bags at 0 or 5°C for up to 2 weeks with no appreciable changes in fruit quality. Fruit of the cultivar, Thiessen, and any other cultivars that are of the same texture and acidity of Thiessen should be able to be stored for 3 weeks under these conditions. Storage longer than this may be possible in MA bags at 0°C if changes in fruit texture and titratable acidity are not undesirable; this needs to be evaluated in future research. Storage in freezer bags at 0°C is likely possible for 1 week, and 2 weeks for the cultivar Thiessen, if the initial microbial count is sufficiently low. Storage in freezer bags at 5°C may be possible for up to 1 week providing that the fruit microbial content is not too high at the time of packaging and the loss in titratable acidity after this time period is not undesirable.

Although changes in fruit quality during storage were significant, they may be undetected by the consumer. Future research should involve the assessment of stored fruit by a sensory panel

to determine at what point quality changes during storage become undesirable. This would enable a more precise determination of the maximum duration of storage capable for various saskatoon cultivars before a noticeable degradation in fruit quality occurs.

MA bags were extremely effective at extending the shelf life of fresh saskatoon fruit. Further research of MA packaging should be focused at determining the optimal bag size for fruit volume, and optimal air removal from the bags for enhancing the benefits of MA packaging. Other types of MA packaging also may warrant investigation.

2.2. Skin Colour Degradation During Storage Of Norland Potatoes And Oxidation Of Processing Cabbage Cultivars

The deep red pigmentation in the skin of Norland potatoes is a desirable fresh market characteristic. During storage, degradation of this red colour to a pinkish-brown colour affects marketing potential. Skin colour in red potato cultivars is due to the presence of anthocyanins. Factors influencing the stability of anthocyanins include light, temperature, oxygen, and pH. Current knowledge on changes in skin colour during storage of Norland potatoes is limited. Research on strawberries and cherries suggests that postharvest colour degradation is do to the action of endogenous polyphenoloxidase (PPO) on anthocyanins. Bruising at harvest, exposure to light, and relatively high storage temperatures enhance anthocyanin degradation in these crops.Undesirable brown discolouration in coleslaw is a major quality problem for the cabbage industry in Saskatchewan. This brown discolouration is due to the oxidation of phenolic compounds by polyphenol oxidase (PPO) and is often controlled by the addition of antioxidants to the processed cabbage. At present, cabbage producers lack knowledge on which local cultivars are more susceptible to browning and processors are unwilling to accept locally grown varieties because of potential problems with the finished product. The major cabbage processor in Saskatchewan currently imports raw cabbage from Ontario and Quebec. The objectives of this component of the program were: 1) to determine at what point in storage colour degradation in potatoes begins; 2) to investigate the factors influencing skin colour degradation of Norland potatoes during storage; 3) if relevant, to determine the appropriate technology to minimize postharvest skin colour degradation; 4) to determine the susceptibility of a number of cabbage cultivars to oxidation during coleslaw processing; 5) to determine the effective types and concentrations of antioxidants to control browning in coleslaw; and 6) to identify a cabbage cultivar which produces well under Saskatchewan growing conditions, while meeting the needs of the processing sector.

The red-skinned potato cultivars Norland, a dark red strain of Norland, Cherry Red and AC Peregrine were stored for five months at 6°C and 90% humidity. Indicators of potato quality (polyphenol oxidase activity and firmness) were monitored during storage to determine the extent of skin colour degradation. In general, potato cultivars did not lose significant firmness during storage. Changes in firmness occurred for the Norland strains, however, these changes were not consistent between the 2 years of the study. Polyphenol oxidase (PPO) activity did not differ among cultivars, nor did it change during storage. Loss of red peel colour did not occur during

the five months of cold storage implying that the majority of colour loss may occur during distribution and marketing and is not a problem during cold storage. Cultivars differed in their firmness and hue angle (red colour). The cultivars Cherry Red and AC Peregrine were firmer and redder than the Norland strains. AC Peregrine was the most firm and red of the cultivars which suggests that there may be a good market potential for this cultivar based on these qualities. AC Peregrine is a new line that is exclusively available to members of the Saskatchewan Seed Potato Growers Association.

Undesirable brown discolouration in coleslaw is a major quality problem for the cabbage industry in Saskatchewan. To offer viable alternatives to the industry, a number of local cabbage cultivars grown at three different locations were evaluated for their susceptibility to browning. The antioxidants ascorbic acid and citric/erythorbic acids were compared to the commercial antioxidant for their effectiveness in preventing browning of coleslaw. Colour quality of coleslaw stored at 4°C was assessed weekly for 3 weeks.

In general, coleslaw became darker and lost green colour during storage. Coleslaw from the cabbage cultivars Almanac, Cecile, Hinova, and Vantage Point had consistently less browning after storage than the cultivar Lennox, which is currently the processing industry's standard. Browning in coleslaw was not directly related to PPO activity. The effectiveness of different antioxidants to control browning and prevent loss of green colour in coleslaw was cultivar dependent. Ascorbic acid was more effective than the commercial antioxidant in preventing oxidative browning for the cultivars Lennox, Storage #4 and Rio Verde, whereas the citric/erythorbic acids were more effective for the cultivar Cecile. The citric/erythorbic acids were more effective at preserving green colour in the cultivars Cecile and Hinova; for the other cultivars, the commercial antioxidant was more effective. The higher the concentration of the antioxidant, the less browning that occurred, however, the lower rate of the antioxidants was better at preserving green colour in coleslaw. Overall, cabbage grown in Saskatoon was less susceptible to browning than cabbage grown in Nipawin or Outlook. It is evident from this study that other cultivars and antioxidants may offer possible solutions to the cabbage industry in Saskatchewan to address the problem of oxidative browning in coleslaw.

3. TECHNICAL REPORT

3.1. Background & Objectives

The mandate of this program was to address some of the postharvest needs of Saskatchewan's Horticulture sector, and in particular, to address issues of postharvest quality in the key areas of fruit and vegetable production.

3.1.1. Shelf Life Extension of Fresh Saskatoon Fruit

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3.2. Year 1 - 1998

3.2.1. Materials & Methods

3.2.1.1. Effect of Storage in Modified Atmosphere Packaging on Saskatoon Fruit Quality

The saskatoon cultivars Smoky, Honeywood, Pembina and Thiessen were used. The first three cultivars were obtained from the University of Saskatchewan plots in Saskatoon, SK. Fruit of the cultivar Thiessen was obtained from a grower's orchard in Waldheim, SK. Fruit were harvested at immature and mature stages of development with reference to the maturity class index for saskatoon fruit (Rogiers and Knowles, 1997).

All fruit were harvested mechanically using a portable hand-held blueberry harvester and catch frame system (Model H, Blueberry Equipment, Inc., Southhaven, MI) and placed in 1 kg plastic trays (Unisource Canada Inc., Saskatoon, SK) with perforations on the top, sides and bottom to allow for removal of field heat (typical dimensions of these trays were 24 cm x 18 cm x 6 cm). To maintain postharvest quality during harvesting, fruit were placed in a cooler. Shelves within the cooler were lined with cryopak ice packs (Cryopak Corp, Vancouver, BC) which had been previously frozen at -40°C. The temperature of the cooling unit (over a 6 h duration) ranged from 3 to 5°C. Fruit were held at this temperature during transportation (up to 2 h) and subsequently held at 0°C prior to cleaning and storage.

Preliminary sorting to remove leaves and twigs was done using a berry cleaner (Hometown Machines, Sundre, AB). Fruit were further sorted manually into immature (red to red-purple) and mature (purple to purple-black) groups. Sorting was done under flourescent light. Additional lighting was supplied by a desk lamp equipped with a 100 W incandescent bulb. Only wholesome fruit were used for experiments. After sorting, 200 g of fruit were weighed into

modified atmosphere (MA) bags (Unisource Canada, Inc., Saskatoon, SK), vacuum sealed (Deli-Vac vacuum machine, Process Plus Inc., Santa Clarita, CA) and immediately placed in storage at 0°C.

To measure fruit colour, 25 g of fresh fruit was cut in halves and placed in a petri dish with seeds facing downwards so that light reflected off the surface of the skin during measurement. Care was taken to ensure that no gaps were left between fruit. Colour measurement was performed using a Hunterlab Miniscan XE (Hunter and Associates, Reston, VA). Hunter L, a, and b values were recorded. After one reading, the petri dish was turned a third of the way and another reading was taken; this was repeated for a total of three readings. Hue angle (degree of redness) was calculated. A high value is indicative of a more reddish hue and a low value, a more purplish hue. Hue angle was calculated using the following equation: Hue ($^{\circ}$)=Tan^{-1}(b/a), where a = Hunter a value and b = Hunter b value.

Texture analysis was performed using a Texture Press (Model TMS-90, Food Technology Corporation, Chantily, VA) equipped with a 140 kg load cell. The attachment used was a Kramer Shear Cell equipped with 13 blades. Fifty grams of fresh fruit were placed in the bottom attachment of the cell. The blades compressed and sheared the fruit at a crosshead speed of 0.35 cm/s. Maximum force (firmness) required to compress and shear the fruit, and the energy consumption or work done (toughness) in cutting through the fruit were used as indices of textural quality. It was assumed that the higher the force and energy value, the firmer and tougher the sample.

To measure the acidity (pH) and soluble solids content, 50 grams of fruit was placed in a sample bag and manually squeezed to extract the juice. The juice extract was poured into test tubes. Soluble solids content of the juice was measured using a handheld refractometer (Fisher Scientific, Model 82322, Japan, Tokyo. Measurements of pH were obtained by inserting the electrode of the pH meter (Model 420A, Orion Research Inc., Boston, MA) into a test tube of the juice extract.

The experiment was replicated three times in a randomized complete block design. Analysis of variance was performed using the GLM procedure of the Statistical Analysis Software (SAS) (version 6.12). Mean separation was accomplished using Duncan's multiple range test.

3.2.1.2. Influence of Harvest Time and Cooling Method on Saskatoon Fruit Quality

Mature saskatoon fruit of the cultivar Honeywood were used for these experiments. Fruit were harvested mechanically at 9 a.m. and at 12 noon, sorted to remove debris using the berry sorter, and packaged in 1 kg plastic trays. Outside air temperatures during harvest were 28°C and 29°C at 9 a.m. and at 12 noon, respectively.

A 1 kg tray was placed at room temperature (23°C) to simulate placing fruit in the shade after harvest. Another kg tray of fruit was placed in a 4°C cooler with frozen ice-packs on the top and bottom. A third kg tray of fruit were dipped in chilled water (1°C) for 1 min. Fruit and water were poured back into trays, slightly shaken to drain off excess water and internal fruit temperature immediately recorded. The fruit were then placed on paper towels to remove any surface moisture and stored at 4°C. This method of cooling was used to simulate rapid removal of field heat. The fourth kg tray of fruit was placed in a 0°C cooler, the typical storage temperature for shelf life studies. The internal temperature of the fruit was monitored over a 24 h period. All fruit were subsequently stored at 0°C for 2 weeks prior to measurement of fruit quality.

Internal fruit temperature was measured using a 8-channel thermistor thermometer (Omega 2166A, Stanford, CT). To measure the internal temperature, fruit were randomly selected and the thermistor probes were placed 3 - 4 mm de[illegible] into the fruit. Temperature was monitored for all eight channels. Fruit that had been measured were discarded and the procedure repeated three times. The internal temperatures of the fruit cooled by the various methods are presented in Table 3.2.1.1.

Statistical analysis was performed as described earlier.

3.2.1.3. Skin Colour Loss During Storage of Red-Skinned Potatoes

Protocols were established to monitor changes in tissue firmness and polyphenol oxidase (PPO) activity during storage. The rationale was that firmness values would provide an index of tissue breakdown and potential release of PPO, which would enhance degradation of anthocyanins in the peel of the potato.

Dark red and regular red Norland potatoes grown during 1998 were obtained from a grower's storage in Bradwell, SK, three times during the storage period (December, February and April). Potatoes were stored at 6°C and 90% relative humidity until required. All chemicals were purchased from Sigma-Aldrich chemicals (Oakville, ON).

To measure potato texture, average-sized potatoes were selected from storage, washed and any surface moisture was removed using paper towels. Potatoes were placed on a cutting board along their longitudinal axes. Sections 2 cm thick along the middle region were marked from the stem to the bud end and cut using a sharp knife. Texture was evaluated by puncturing the surface of the section with a 2 mm diameter probe attached to a TA.XT2 texture analyzer (Texture Technologies Corp., Scarsdale, NY). Five punctures were made on the surface of each potato, one each at the stem end, pith and bud end and two in the parenchyma tissue on each side of the tuber outside of the vascular ring. The probe was allowed to puncture halfway into the tissue (i.e.1 cm from the surface). Peak force, the maximum force required to puncture the tissue, was used as an index of firmness. High peak force is indicative of a firm potato and vice versa. Two measurements were taken for each potato. Three potatoes were analyzed in each

replicate.

To measure polyphenol oxidase activity, average-sized potatoes were randomly removed from storage, washed and peels removed as thinly as possible. Peels were placed in sample bags and immediately frozen at -40°C. Potato flesh was chopped, placed in a Waring blender with enough water to over the top, and homogenized for 25 s. The homogenate was allowed to settle for 5 min and filtered through Whatman #4 filter paper. The filtrate containing the crude enzyme extract was placed in test tubes and held in a water bath at 30°C for at least 1 h prior to measurement of enzyme activity. The substrate for PPO was 0.01 M catechol in 0.1 M phosphate buffer, pH 6.0. To monitor enzymic browning, 4 mLs of catechol solution were added to 1 mL of water and 0.05 mLs of crude enzyme extract. Increase in absorbance at 410 nm was measured using a Beckman spectrophotometer (Model DU^R-64, Fullerton, CA). Absorbance readings were recorded every 15 s for 2 min and every subsequent minute for 15 min. A blank solution containing 5 mLs of water and 5 mLs of crude enzyme extract was used to standardize the spectrophotometer. Progress curves indicating the activity of the enzyme with respect to time were plotted. A tangent was drawn to each curve at zero time and PPO activity was calculated directly as the increase in absorbance at 410 nm per minute. Three replicates were performed and two potatoes were used in each replicate.

3.2.1.4. Oxidative Browning of Coleslaw

Protocols were established to measure colour quality of coleslaw using a Hunter colorimeter. Commercial antioxidant was obtained from a coleslaw manufacturer (Delsa foods, Delisle, SK) to compare the industry's standard antioxidant to other potential antioxidants. The Canadian Food Inspection Agency was contacted for information on antioxidants permitted for use in coleslaw and acceptable levels. Ascorbic acid and citric/erythorbic acids are currently permitted for use.

The processing cabbage cultivars Cecile, Hinova, Lennox, Rio Verde and Storage #4 grown at Nipawin, Outlook and Saskatoon were harvested at maturity, lightly trimmed, then stored at 0°C until required. Cabbage was randomly taken from storage, the outer leaves were removed and the head was washed, cored, cut and processed for 1 min (PowerPro Food Processor, Black and Decker, Brockville, ON) using standard blades for commercial processing. After processing, 300 g portions of processed cabbage (referred to hereinafter as coleslaw) were mixed throughly with an antioxidant. Ascorbic acid was added at 150, 300, or 600 ppm, or citric/erythorbic acids were added at 2000/400, 2400/800 or 2800/1200 ppm. The treated coleslaw was placed in ziploc bags with as much air as possible removed. The coleslaw was stored for 3 weeks at 4°C. This is the temperature at which coleslaw is held prior to shipping out from the processing plant, and the storage temperature of coleslaw in retail outlets. Samples of coleslaw were analyzed weekly for colour using a Hunterlab colorimeter (Model 45/0, Hunter Associates, Reston, VA).

All treatments were replicated three times in a randomized complete block design.

Analysis of variance was performed using the GLM procedure of the Statistical Analysis Software (SAS) (version 6.12). Treatment differences were determined by Duncan's multiple range test ($p \leq 0.05$).

Table 3.2.1.1. Internal temperature of saskatoon fruit cooled by various methods.

Harvest Time	Sampling Time (h)	Air T (°C)	Cooling Method			
			Room T (°C)	0°C	4°C	Pre-dip & 4°C
9 am	0	22-23	23-25	23-25	23-25	36115
	1.5	22-23	23-25	16-18	16-20	36115
	2.5	23-24	23-24	15-17	14-18	36144
	6	23-24	23-24	36144	36174	36115
	7.5	23-24	22-24	36146	36145	36112
	24	23-24	23-24	36112	36114	36177
12 noon	0	28-29	26-27	26-27	26-27	15-17
	1	23-24	23-25	14-17	15-19	14-17
	2.5	23-24	22-24	36177	36145	36143
	19	23-24	23-24	36143	14-18	14-18
	24	23-24	24-25	36146	15-18	36177

3.2.2. Results, Discussion & Conclusions

3.2.2.1. Effect of Storage in Modified Atmosphere Packaging on Saskatoon Fruit Quality

Figure 3.2.2.1 shows the effects of storage period on fruit hue angle, firmness, and toughness, and Figure 3.2.2.2. demonstrates the effects on fruit pH and soluble solids content. Changes in colour quality during storage were dependent on maturity stage. The hue angle of mature fruit of Honeywood and Smoky fluctuated during storage, whereas the changes in hue angle during storage of mature fruit Thiessen and Pembina were generally non-significant. Colour changes of immature fruit of Smoky and Thiessen during storage were also non-

significant, however fruit of the cultivar Honeywood experienced a consistent decrease in colour between 9 and 48 days of storage (possibly an indication of fruit ripening). Variation in fruit colour is to be expected due to unevenness of colour on a single fruit.

Changes in firmness and toughness during storage were generally not significant for most cultivars and maturity classes except for fruit of the cultivar Thiessen (mature and immature) which increased significantly in fruit texture during storage. Immature fruit of the cultivar Smoky also showed a significant increase in toughness.

Changes in fruit pH and soluble solids content during storage were not significant regardless of cultivar or maturity stage. Changes in pH and soluble solids are indicative of changes in fruit flavour and thus the results imply that changes in flavour were generally unaffected during storage.

Hue angle, firmness and toughness values were significantly higher for immature fruit than for mature fruit (Figure 3.2.2.3). These results are consistent with the findings of Rogiers and Knowles (1997) which indicate that during development and maturation, saskatoon fruit change colour from green to red to purple. This colour change is due to the synthesis of anthocyanin pigments which occurs concomitantly with the degradation of chlorophyll. Textural changes in immature fruit as they approach maturity result in a decrease in firmness. These textural changes associated with fruit softening are primarily due to the breakdown of insoluble structural components such as the pectic polysaccharides and starch to more soluble components namely pectic acid and sugars, respectively. This increase in the soluble components of mature fruit is shown in Figure 3.2.2.4. No significant changes in fruit acidity (pH) were found between mature and immature fruit (Figure 3.2.2.4.).

The saskatoon cultivars Smoky, Pembina, Thiessen and Honeywood were used to examine cultivar differences in fruit quality during storage. These cultivars were examined at both mature and immature stages of development. Due to an insufficient sample size, the immature class of fruit of the cultivar Pembina was not examined. The colour, texture, pH and soluble solids varied among cultivars for both mature and immature fruit (Figures 3.2.2.5. to 3.3.3.8.). Fruit of the cultivar Thiessen consistently had significantly lower pH and soluble solids than that of Honeywood and Smoky. Fruit of the cultivar Thiessen tended to be less firm and less tough than fruit of the cultivar Honeywood, although not consistently. Fruit of the cultivar Honeywood had the highest pH and soluble solids content of the cultivars. Cultivar differences are dependent on several extrinsic and intrinsic factors such as location, crop year, cultural practices, chemical composition of the fruit, fruit size and the number of seeds per fruit. Since these differences between cultivars were examined for a single crop year, these results might vary from one year to the next.

3.2.2.2. Influence of Harvest Time and Cooling Method on Saskatoon Fruit Quality

Tables 3.2.2.1. and 3.2.2.2. present the effects of harvest time and cooling method on fruit quality. Interactions between harvest time and cooling method were not significant for all quality parameters. No significant differences were found between fruit harvested at 9 a.m. or 12 noon in their hue angle, toughness and soluble solids content. Fruit harvested at 12 noon were firmer and more acidic than fruit harvested at 9 a.m.

No significant differences were found between cooling methods for all quality measurements except for pH. Rapid removal of field heat by dipping fruit in chilled water for 1 min prior to storage at 4°C was effective at cooling the fruit more rapidly (Table 3.2.1.1.), however, it also resulted in a higher fruit pH after 2 weeks in storage and no other improvements in fruit quality relative to that of the other cooling methods. It is not known why this would occur as a more rapid cooling should have reduced fruit respiration faster and preserved fruit acidity. A longer dipping period may yield a more rapid removal of field heat and more significant differences in postharvest quality.

3.2.2.3. Skin Colour Loss During Storage of Red-Skinned Potatoes

Two strains of Norland potatoes (regular and dark reds) were monitored for changes in firmness (peak force) and PPO activity during storage. Overall, no significant differences were found between the two strains (Table 3.2.2.3.) with respect to peak force or PPO activity. The effect of storage period on these properties is shown in Table 3.2.2.4. There were no significant changes in PPO activity during storage for either the regular reds or for the dark reds. A significant decrease in peak force was found for regular reds from December to February and for the dark reds from February to April. The results also indicated that the dark reds were significantly softer at the start of the storage period than regular reds but as storage progressed, the dark reds became significantly firmer, whereas the regular reds became softer. Changes in firmness during storage are indicative of physiological changes in potato tissue. Some of these changes include moisture loss and solubilization of starch and pectic polysaccharides.

Visual observation of peel colour during storage suggests that there was minimal degradation in colour quality. The hypothesis of this research is that decrease in firmness and release of PPO from potato flesh into the peel is responsible for skin colour degradation in Norland potatoes. These results imply that the changes leading to breakdown in skin colour are probably accelerated by handling and storage management practices during the distribution chain.

3.2.2.4. Oxidative Browning of Coleslaw

The Hunter L value can give an indication of the degree of darkening resulting from oxidation of phenolic compounds by polyphenol oxidase (Skog *et al.* 1998). These authors reported that Hunter L value correlated strongly to visual colour changes as recorded by a

sensory panel. The Hunter a value can provide a measure of green colour loss in coleslaw. Results for Hunter L and a values are shown in Figure 3.2.2.9.

Regardless of growing location, the cultivars Hinova and Cecile consistently had higher L values than all other cultivars evaluated in the study (Figure 3.2.2.9.A). This suggests that these cultivars are less susceptible to oxidation. Storage #4 and Rio Verde appeared to be more susceptible to oxidation than Hinova and Cecile, but Lennox was the most susceptible cultivar. These results have significant implications for the cabbage industry in Saskatchewan in that Hinova and Cecile have processing capabilities that far exceed those of Lennox, currently the standard for the major cabbage processor. All cultivars grown in Saskatoon were less susceptible to oxidation (shown by the higher L values) than those grown in Nipawin and Outlook. This is possibly a function of soil type and climatic conditions.

The cultivar Storage #4 generally had lower Hunter a values, and thus a greater loss of green colour than Rio Verde, Hinova and Cecile (Figure 3.2.2.9.B). Cultivars grown in Saskatoon had significantly higher Hunter a values compared to those grown in Nipawin.

The overall effect of storage period on coleslaw colour quality is shown in Table 3.2.2.5. As storage progressed, a degradation in colour quality due to significant darkening (a decrease in Hunter L value) occurred in coleslaw samples. Coleslaw also lost green colour (an increase in the Hunter a values) during storage.

The effectiveness of antioxidants in controlling oxidation and loss of green colour was cultivar dependent (Figure 3.2.2.10.). Ascorbic acid appeared to be an effective antioxidant for Lennox and Storage #4 whereas citric/erythorbic acids controlled oxidation in Cecile. The commercial antioxidant was not as effective as ascorbic acid in controlling oxidation in Storage #4, Rio Verde, Hinova and Lennox. Loss of green colour was significantly less in Lennox and Storage #4 treated with the commercial antioxidant, and in Hinova and Cecile containing citric/erythorbic acids.

Overall, the higher the concentration of citric/erythorbic acids, the better was the control of oxidative browning as indicated by higher L values (Table 3.2.2.6.). For ascorbic acid, there was no significant difference in Hunter L value at 300 and 600 ppm but a significant decrease in the L value was observed at 150 ppm. However, the loss of green colour was the least at the lowest concentration of antioxidants.